HIGH RATE IRRIGATION FOR GROUNDWATER RECHARGE

Henriette M. Emond[1]
Mark F. Madison[2]
Frank Sinclair[3]

ABSTRACT

With the establishment of Total Maximum Daily Loads (TMDLs) for Oregon rivers and increasingly stringent regulatory limits on surface water discharges, municipalities are faced with mounting challenges on discharging effluent. Effluent containing relatively high temperature levels or nutrients can not be discharged to rivers during times of low flow, principally in the summer. To address this issue, municipalities are examining other alternatives for treatment and discharge.

This paper highlights the benefits of a wastewater treatment alternative using a high rate effluent irrigation system and provides a description of a study that is being used to validate those benefits. In the study, wastewater is applied to a crop at rates greater than agronomic rates and is allowed to percolate below the root zone for eventual groundwater recharge and ultimate groundwater discharge to the nearby river. As the water slowly moves through the root zone, nutrients in the water are transformed in the soil and are taken up by the crop. The water temperature is also cooled through the interaction with the groundwater. The potential benefits from these systems include: increasing the amount of wastewater that can be applied per unit land area; improving the water quality of excess effluent irrigation water moving through the root zone which ultimately recharges groundwater and discharges to the river; and increasing the amount of water supporting the river flow as compared to strictly agronomic rate irrigation over a greater land base.

A high rate effluent irrigation program is being evaluated at two different sites in Western Oregon to collect data on this concept. The information will be analyzed to evaluate the performance of a poplar tree reuse system in polishing advanced secondary treated wastewater to remove nutrients and increase the quality of water. During the summer growing season, plots will be irrigated at 100 percent, 150 percent, 200 percent, and 400 percent of agronomic rates. Data will be

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[1] Senior Technologist, CH2M HILL, 2020 SW 4th Avenue, Suite 300, Portland, OR 97201; henriette.emond@ch2m.com
[2] Principal Technologist, CH2M HILL, 2020 SW 4th Avenue, Suite 300, Portland, OR 97201; mark.madison@ch2m.com
[3] Frank Sinclair, Superintendent Wastewater Treatment Plant, 2815 Molalla Road, Woodburn, OR 97071; Frank.Sinclair@ci.woodburn.or.us

collected to monitor the soil moisture and the vadose zone water quality associated with each of these rates of irrigation, in the root zone and just below the root zone.

Installation of irrigation and monitoring equipment for the study was begun during the summer of 2005 and 2006. Data will be collected and analyzed through the spring, summer, and fall of 2006 and 2007. Preliminary results should be available by October 2006.

BACKGROUND

Around the country, Total Maximum Daily Loads (TMDLs) are being considered as a means of controlling the loading of pollutants to our nation's rivers. With the establishment of TMDLs for Oregon rivers and increasingly stringent regulatory limits on surface water discharges, municipalities and industries are faced with mounting challenges when discharging effluent. Effluent containing relatively high temperature levels or nutrients can not be discharged to rivers over a certain load, especially during times of low flow which occurs principally in the summer.

With the proposed TMDLs and the associated new National Pollutant Discharge Elimination System (NPDES) permits, the temperature and ammonia regulations will extend beyond just the two peak summer months. Excess temperature and nutrient loading in the fall is becoming a concern. This is the time when river temperatures generally drop, fish spawning is commencing, and effluent temperatures continue to remain relatively high.

To address these loading issues, municipalities are examining a variety of alternatives for treatment and discharge. Because cost is a major consideration in any treatment plant improvement, natural treatment systems and land application alternatives are being closely examined as a means to achieving the desired constituent load reductions at less cost. In addition, the sustainable aspect of a natural treatment solution requiring less chemical additions and less infrastructure further bolsters its appeal.

One of the alternatives being considered is land application through high rate irrigation. For example, the Oregon-based research organization, SPROUT, is providing grant funding assistance to the City of Woodburn to conduct a study of high rate irrigation of poplar trees. The study is being conducted at Oregon Gardens, in parallel to a demonstration site to be established and evaluated during 2006 at the City of Woodburn's Wastewater Treatment Plant site.

Monitoring parallel research at two similar sites will increase the confidence that the data is representative of poplar tree treatment performance in the Willamette Valley. These two sites will provide information to regulators and the public and provide greater understanding of the site and monitoring designs and data to support more communities in utilizing sustainable plant systems as a part of their environmental compliance.

The target audiences for this type of project are communities interested in poplar tree technology for wastewater reuse, as well as regulating agencies involved in wastewater quality regulation. In addition, the general public will become more educated in the process of poplar tree water quality improvement and sustainable treatment.

PROJECT OBJECTIVE

The purpose of this study is to evaluate the effectiveness of using high rate irrigation of poplar trees to polish applied water percolating below the root zone.

In the study, wastewater is applied to a crop at rates greater than agronomic rates, and is allowed to percolate below the root zone for eventual groundwater recharge and ultimate groundwater discharge to the nearby river.

It was proposed that a highly monitored and controlled research site at the existing mature poplar reuse farm at Woodburn, in parallel with a comparable study at Oregon Gardens, could provide the data to determine the optimal irrigation rate for beneficial reuse and groundwater recharge. A demonstration plot of poplar trees within Oregon Gardens and a parallel portion of the research study at Woodburn's wastewater treatment plant poplar tree plantation would be both irrigated at higher than agronomic rates.

The goal of the parallel research at Woodburn and at Oregon Garden is to produce data to support irrigation rates higher than crop consumption rates. A monitored and controlled research site at the existing mature poplar reuse plots can provide the data to determine the optimal irrigation rate for beneficial reuse and groundwater recharge. The higher rate irrigation will maximize the benefits of utilizing the natural plant system as a water purification system rather than just a water consumption system. In addition, this increases the per acre capacity of a land application reuse site. This feature is particularly attractive under conditions of scarce or costly land resources.

This alternative tests the hypothesis that irrigation at higher rates remains protective of groundwater quality. If this is true, it will allow the waste water treatment plant to land apply effluent on a smaller acreage than with agronomic irrigation rates rather than discharge the same amount of water to the river. The poplar trees do not need to consume all of the water to consume the nutrients that the water contains.

As the water slowly percolates through the root zone, nutrients in the water are transformed in the soil and are taken up by the crop. Nutrients are removed and water below the root zone then may meet drinking water standards. The water temperature is also cooled through the interaction with the groundwater.

Recharge of drinking water quality water to the shallow aquifer at the site near the river can enhance the flow of cool water to the river from springs during low flow periods. The total annual volume of water discharged to the river would be similar

to the current volume discharged from the outfall pipe. However, the water would be further treated by the extensive root system of the poplar trees and would be discharged through natural springs with the cool shallow groundwater. It is anticipated that the net environmental impact of higher rate irrigation would be positive.

The potential benefits from these systems include: increasing the amount of wastewater that can be applied per unit land area, improving the water quality of excess effluent irrigation water moving through the root zone which ultimately recharges groundwater and discharges to the river, and increasing the amount of water supporting the river flow as compared to agronomic rate irrigation over a greater land base. The application of agronomic-rate irrigation over a greater land base does not provide increased flow benefits to the river.

The data is intended to support the goal of gaining public support for beneficial reuse by expanding the understanding of plants as a sustainable natural treatment system. Confirmed data and information from the pilot sites will establish design criteria for a full-scale program.

PROJECT DESCRIPTION

The high rate effluent irrigation program is being tested at two different sites in Western Oregon to collect data on this concept. The information will be analyzed to evaluate the performance of a poplar tree high rate irrigation reuse system in polishing advanced secondary treated wastewater to remove nutrients and increase the quality of water. During the summer growing season, plots will be irrigated at 100 percent, 150 percent, 200 percent, and 400 percent of agronomic rates. Data will be collected to monitor the soil moisture and the vadose zone water quality associated with each of these rates of irrigation, in the root zone and just below the root zone.

The 2 sites involved in the study already have established poplar tree plantations that are approximately 8 years old. At both sites, the trees are irrigated with an above-ground solid set spray irrigation system with flow rates ranging from 0.5 to 10 gallons per minute (gpm). The total amount of water applied is dependent on duration of application.

One of the sites is located at Oregon Gardens in Silverton, Oregon. At this site, the plot is approximately 1 acre of 8- to 10-year old poplar trees, with a solid set spray irrigation system installed along the centerline of the plot. Trees are planted approximately 10 feet apart and risers are located 30 feet apart. The irrigation system is equipped with Nelson rotator nozzles with an application rate ranging from 2.5 gpm to 10 gpm. Three separate groups of trees were retrofitted with three different nozzles so that irrigation durations could remain the same for the site, with the application rate varying by nozzles.

During the 2005 summer, the irrigation ran 6 hours a day, 3 days a week during the summer months. Agronomic irrigation application occurs with the nozzles

having a flow rate of 2.5 gpm. Increased irrigation application occurs on the other nozzles which have flow rates of 3.5 gpm, 5 gpm, and 10 gpm, irrigated for the same duration. During the 2006 season, a change in operating personnel resulted in deficit irrigation on most of the plot in July and part of August, but the irrigation application was increased in August and September to compensate for this shortfall.

During the winter, which is the wet weather season, the irrigation is shut off and winter rains saturate the soil. Over the course of this time, any constituents applied with the irrigation water during the summer, including nitrogen, are flushed through the soil. Data is collected on the input water quality and the water quality of the soil water during the flush.

The other high rate irrigation study site is located at the City of Woodburn Waste Water Treatment Plant Poplar Tree Plantation located in Woodburn, Oregon. Woodburn has used poplar trees for summer effluent reuse for over 8 years. The entire plantation totals 80 acres, with 8-year old and older poplar trees. The City has always irrigated the trees at agronomic rates.

At the Woodburn Wastewater Treatment Plant Poplar Tree Plantation, the high rate irrigation program will be tested on 2 of the 7-acre management units, for a total of 14 acres. The high rate irrigation may not begin until fall 2006, due to permitting constraints.

The site is irrigated with a solid set micro-spray irrigation system with risers spaced 20 feet apart down the rows and 13 feet apart between rows. Trees are spaced at 12 feet down the rows and 13 feet between rows. The irrigation system has nozzles with an application rate of 0.5 gpm. However, in the high rate irrigation section of the plantation, the nozzles are sized for flows ranging from 0.5 gpm to 1.0 gpm.

During high rate irrigation application on the demonstration plots at Woodburn, water will be applied at 150 percent, 200 percent, and 400 percent of the irrigation requirement. The high rate irrigation application will be accomplished in two ways: (1) installing higher rate micro-spray nozzles than currently in use on the Woodburn plantation to achieve a higher application rate per unit of time, and (2) extending the amount of time during which the plot is irrigated.

To achieve 150 percent of the gross irrigation requirement, the nozzles on the west half of Management Unit (MU) 11 at Woodburn, will be changed from 0.5 gpm to 0.75 gpm. The east end of MU11 will remain unchanged, and the entire MU11 will maintain a schedule matching gross irrigation requirement.

To achieve an application of 200 percent of the gross irrigation requirement, the micro-sprayers on the east half of MU12 at Woodburn will keep the same nozzles; however, the irrigation duration will be extended in order to apply twice the amount of water than required to meet the monthly gross irrigation requirement. To achieve an application of 400 percent of the gross irrigation

requirement, the duration on the west half of MU12 will also be extended so that the application rate is doubled using the existing nozzles, and, in addition, the nozzles on the micro-sprayers in the west half of MU12 will be changed from 0.5 gpm to 1.00 gpm so that twice the volume of water can be applied per unit of time.

At the Woodburn plantation, the irrigation runs 2 hours a day, 7 days a week during the summer months. For the high rate irrigation study, some of the plots will be run for a longer duration to achieve the targeted irrigation rate.

Water will be applied on the poplar trees at rates exceeding irrigation requirements during the months of April through October. With the new NPDES permit, the temperature regulations will extend beyond just the 2 peak summer months. Therefore, the high rate irrigation application will be extended from the past practice of limiting irrigation to July and August.

During the study, because of the reuse systems maturity, the City of Woodburn has the flexibility to apply varying amounts of water, depending on the waste water treatment plant's discharge constraints. The current design flow to the poplar reuse system is 0.9 million gallons per day (mgd). The City has analyzed the alternative for reducing river discharge by expanding the poplar reuse system onto the waste water treatment plant's adjoining property.

As at the Oregon Garden site, the irrigation at the Woodburn site is shut off during the winter when the winter rains saturate the soil. During that time, the constituents applied with the irrigation water, including nitrogen, are flushed through the soil.

The Study Schedule

Installation of irrigation and monitoring equipment for the study was begun during the summer of 2005 and extended into the summer of 2006. Data are collected and analyzed from the winter of 2005 through the summer of 2007. Preliminary first year results should be available by October 2006.

The high rate irrigation project is scheduled to run from 2005 through the 2007 irrigation season. In the beginning of July 2005, nozzles of varying flow rates were installed and high rate irrigation begun at the Oregon Garden. Lysimeters were installed at the Oregon Garden site in the fall of 2005, and collection of soil water data began during the winter of 2006. Lysimeters were installed at the Woodburn site in August 2006, with background soil water data collected before irrigation began.

Project Participants

The project participants include staff from the City of Woodburn, Oregon Gardens, and CH2M HILL. The City of Woodburn Wastewater Treatment Plant staff will manage the irrigation system; perform the field work; and provide water quality equipment installation and monitoring, collect samples, and provide analysis. CH2M HILL staff is assisting in the monitoring equipment installation, and are primarily responsible for analyzing the data and reporting on the sites' performance. Oregon Gardens staff participates by appropriately scheduling the irrigation for high rate application and observation of the poplar tree plots. The Woodburn staff collects samples, gathers data from the lysimeters, and performs water quality analysis on the samples at Oregon Gardens site, and will do the same at the Woodburn site.

Monitoring System

For both systems, lysimeters are installed in the middle of each plot irrigated at different high rate application rates. Lysimeters are installed at a depth of 6 feet and are monitored on a monthly basis. Tensiometers will be installed at the Woodburn plot and during the summer they will be monitored weekly.

Long term weather data for precipitation and reference evapotranspiration have been obtained from a nearby weather station to verify agronomic rate irrigation application. The lysimeters will allow collection of soil pore water samples from the vadose zone below the tree roots but above the groundwater table. Water quality at this depth is expected to meet drinking water standards and may be further polished before it reaches the shallow aquifer. The sampling above the aquifer means that our soil water quality results are not impacted by groundwater. The tensiometers will provide soil moisture content data and indicate flux to groundwater.

Relevant monitoring currently being done at the wastewater treatment plant site will be incorporated into the results evaluation. The lysimeter samples are analyzed in the Woodburn water quality lab for the drinking water standards that the Woodburn lab is capable of performing, and a split sample is sent to an approved lab for the balance of the analysis.

CH2M HILL will review the lab data, make recommendations for the operation of the research site, and prepare the data evaluation report and recommendation for optimum irrigation rates for the poplar farm.

Results

The preliminary results of the nitrate concentration in the soil water samples taken at the high rate irrigation site at Oregon Gardens since January 2006 are presented in Figure 1, along with the nitrate concentrations of the application water. The center-right part of the Figure, from January to April 2006, shows the

concentration of nitrates in the winter for lysimeters in 100 percent, 150 percent, 200 percent and 400 percent of agronomic rate irrigation after one season of high rate irrigation. The concentration of nitrates in the soil water range from 1.7 to 4.5 mg/L for 100 percent, 150 percent, and 200 percent of agronomic application rate during that time. However, soil water concentrations of nitrate are noticeably higher for the 400 percent of agronomic application rate. Nitrogen concentration in the applied water for the irrigation site in 2005 and 2006, and range from 4 to 11 mg/L.

A portion of the data still needs to be collected and reviewed for the latter part of the summer and the fall months of 2006.

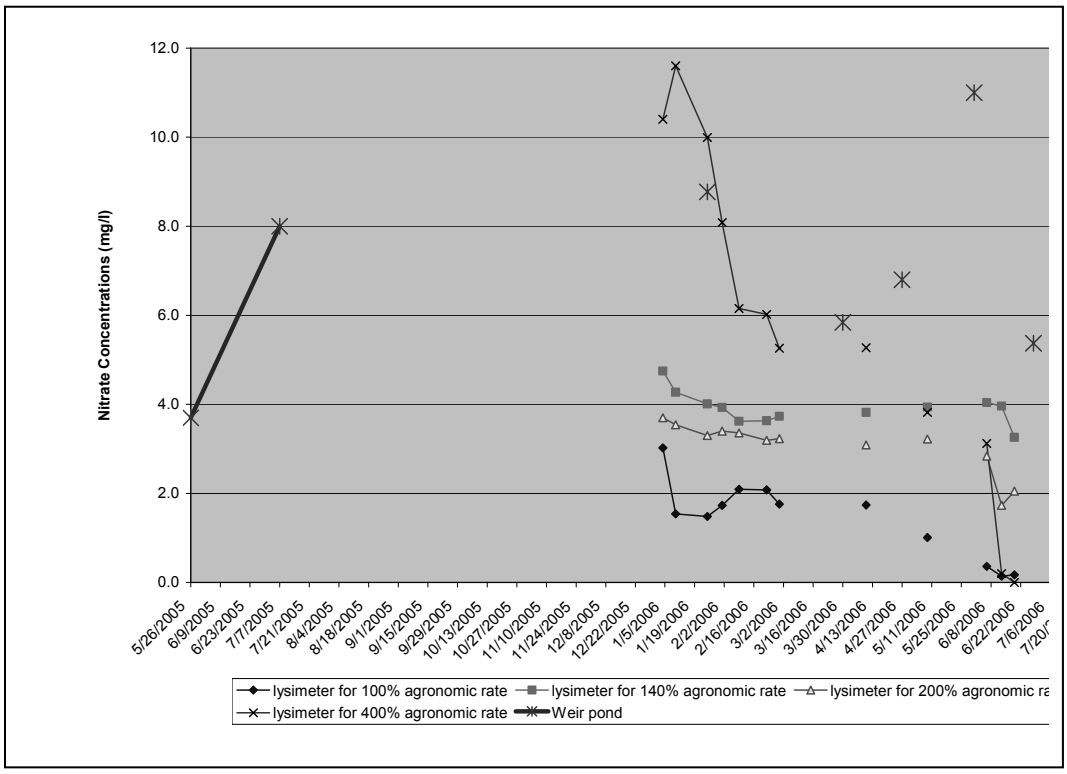

Figure 1. Oregon Poplar Tree Irrigation Applied Water and Soil-Water Nitrate Sampling